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SAST - Shrimp

SYNOPSIS OF BIOLOGICAL DATA ON THE BROWN SHRIMP
Penaeus aztecus aztecus Ives, 1891

Exposé synoptique sur la biologie de
Penaeus aztecus aztecus Ives, 1891

Sinopsis sobre la biología del
Penaeus aztecus aztecus Ives, 1891

prepared by

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1/ This synopsis has been prepared according to Outline Version No. 2. (H. Rosa Jr., FAO Fish.Synops., (1) Rev.1, 1965).

* As no information was available to the author, these items have been omitted from the text.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Penaeus aztecus aztecus Ives, 1891

1.12 Objective synonomy

Penaeus brasiliensis, var. azteous Ives, 1891, Proc.Acad.Natur.Sci.Philadelphia, XLIII:190.

Penaeus aztecus Ives, "Form A", Burkenroad, 1939, Bull. Bingham oceanogr. Colln. 6(6): 26,27,34-45,figs.20,21,24,30,31.

Penaeus aztecus aztecus Ives, Pérez-Farfante, 1967, Proc.biol.Soc.Wash.(8): 87, 93.

1.2 Taxonomy

1.21 Affinities

Suprageneric (to family after Waterman and Chace, 1960)

Phylum Arthropoda
Class Crustacea
Subclass Malacostraca
Series Eumalacostraca
Superorder Eucarida
Order Decapoda
Suborder Natantia
Section Penaeidea
Family Penaeidae
Subfamily Penaeinae

Generic

Genus Penaeus Fabricius, 1798, Suppl. Ent.Syst.:385,408. Type species by selection by Latreille, 1810, Consid.gén.Anim.Crust. Arachn.Ins.:102,422:Penaeus monodon Fabricius, 1798, Suppl.Ent.Syst.:408. Gender: masculine.

Definition

Rostrum toothed dorsally and ventrally. Carapace without longitudinal or transverse sutures; cervical and orbito-antennal sulci and antennal carinae always present. Hepatic and antennal spines pronounced, pterygostomial angle rounded. Telson with deep median sulcus, without fixed subapical spines, with or without lateral movable spines. First antennular segment without a spine on ventral distomedian border. Antennular flagella shorter than carapace. Maxillulary palp with 2 or 3 segments, usually 3. Basial spines on 1st and 2nd pereiopods; exopods on 1st 4 pereiopods, usually present on 5th. Petasma symmetrical, pod-like with thin median lobes with or without distal protuberances; lateral lobes often with thickened ventral margin. Appendix masculina with distal segment subtriangular or ovoid, bearing numerous spines. Thelycum usually with an anterior process, variable in shape, lying between the coxae of 4th pereiopods; with or without lateral plates on sternite XIV. Pleurobranchiae on somites IX to XIV: a rudimentary arthrobranch on somite VII and a posterior arthrobranch on somite XIII; mastigobranchiae on somites VII to XII. Zygocardiac ossicle consisting of a principal tooth followed by a longitudinal row of smaller teeth which often end in a cluster of minute teeth. Body glabrous. (After Dall, 1957, slightly modified by Pérez-Farfante).

Specific

Type specimen

Neotype and neoparatypes of P. aztecus were selected by Burkenroad (1939) from specimens of Penaeus brasiliensis azteous Ives from Veracruz, Mexico. They are on deposit in the Philadelphia Academy of Natural Sciences, Reg. No. P.A.N.S. 61. The type specimens selected for P. aztecus are also applicable to P. a. aztecus as this is the nominal subspecies.

Diagnosis

Adrostral carina reaching almost to posterior margin of carapace; adrostral sulci deep, long, broad, and of rather uniform width, not tapering or turning laterally at posterior end; median sulcus deep, continuous and long; gastrofrontal carina present, straight, not forming a loop at the posterior end; rostrum with more than 1 ventral tooth; coxae of chelipeds unarmed; dorsolateral sulci of 6th abdonimal segment wide, relation between keel height and sulcus modally 1.25; female with carina of posteriomedian elevation of median plate of XIII bifurcate; anteromedial corners of lateral plates of adult thelycum not extended, not converging medially, nor covering carina of posteriomedian plate of XIII; ventral surface of lateral plates of thelycum not pubescent; tip of distoventral lobe of male petasma not projecting; spines absent from external edge of distoventral lobe of petasma; ventral costa of petasma markedly convex distally, armed with a compact, elongate patch of small teeth on the attached edge; outer margin of appendix masculina of 2nd pleopods more or less straight, or only slightly concave. (Burkenroad, 1934, 1939; Anderson and Lindner, 1943; Pérez-Farfante, 1967).

Key to species

For key to species of the western Atlantic see section 1.21 of synopsis on Penaeus schmitti by Isabel Pérez-Farfante (1970).

1.22 Taxonomic status

P. aztecus and its 2 subspecies P. a. aztecus and P. a. subtilis Pérez-Farfante, were established on morphological characters. P. a. aztecus is also geographically distinct from P. a subtilis (Pérez-Farfante, personal communication). It also appears to be physiologically different from P. duorarum duorarum Burkenroad, which is closely related and has about the same geographical distribution as P. a. aztecus. Important points of difference are time of spawning, depth distribution of adults, and preference for different bottom types.

1.23 Subspecies

Penaeus aztecus is composed of 2 subspecies, P. aztecus aztecus in the north and P. aztecus subtilis Pérez-Farfante, which "ranges from Cuba along the arc of the Antilles, and from south of Cape Catoche throughout the Caribbean coast of Central and South America, and along the northern and eastern coast of South America, to at least Cape Frio, Brazil." (Pérez-Farfante, 1967).

1.24 Standard common names, vernacular names

United States: brown shrimp
Mexico: camarón cafe, or camarón moreno

1.3 Morphology

1.31 External morphology

Williams (1965) described the color. "Juveniles and young adults from estuaries or oceanic water near shore are usually brown or grayish brown, occasionally with darker spots or faint concentrations of chromatophores at the pleural articulations. Individuals from deeper water are light orange (Burkenroad, 1939). The tail fan is darkened distally and in adults is edged with purple to reddish purple." White, green, and red color phases have also been observed, and, occasionally, P. aztecus bears the same abdominal spots as P. duorarum (Eldred and Hutton, 1960).

1.33 Protein specificity

Leone and Pryor (1952) made serological comparisons of saline-haemocyanin filtrates of P. aztecus, P. setiferus, and P. duorarum from North Carolina. Their results placed the brown shrimp P. aztecus and the pink shrimp P. duorarum closer to each other than either of them was to the white shrimp P. setiferus. P. aztecus was less similar to P. setiferus than was P. duorarum. These authors stated "The serological differences are significant, and support the theory that these organisms are three distinct, but closely related, species."

2 DISTRIBUTION

2.1 Total area

According to Pérez-Farfante (personal communication), P. aztecus aztecus is limited to the east coast of the United States and the Gulf of Mexico; under the FAO distribution code (Holthuis and Rosa, 1965), this region corresponds to the coasts of areas 235, 237, 238, and 311. On the east coast of the United States the distribution ranges from New Jersey (occasionally to Martha's Vineyard, Massachusetts) south to Florida, then through the Gulf of Mexico to about Campeche, Mexico (Williams, 1965). For many years the shrimp was thought to be absent from the southern Florida waters, but recently a few specimens have been taken from off the Florida Keys and northern Sanibel grounds (Costello and Allen, 1964) and from Everglades National Park (Tabb, Dubrow and Jones, 1962). On the Atlantic coast, it is most abundant in North and South Carolina; in the Gulf of Mexico the center of abundance is off Texas and eastern Mexico.

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles

Eggs and larvae occur in all offshore waters inhabited by the adults. Normally, the young shrimp enter the estuarine nursery areas as postlarvae 8 to 14 mm total length (tip of rostrum to tip of telson). After spending about 3 mo on the nursery grounds, the shrimp move back to offshore waters at a total length of about 100 mm.

2.22 Adults

See sections 2.1, 3.51, and 5.31.

2.3 Determinants of distribution changes

The determinants of distribution changes are largely unknown.

Gunter, Christmas and Killebrew, (1964) have shown that salinity seems to be a limiting factor in the distribution and abundance of P. aztecus and related species. Juvenile brown shrimp were most abundant in estuarine water of 10 to 20‰ salinity, whereas P. setiferus was most abundant at salinities lower than 10‰, and P. duorarum was most abundant at salinities of 18‰ and above. They also pointed out that in the United States most white shrimp are taken off Louisiana, where the inside waters are relatively fresh. The greatest concentration of brown shrimp is off Texas where bay salinities are generally higher than in Louisiana, and pink shrimp are taken mostly around the south Florida islands where salinities are oceanic.

Zein-Eldin (1963) reported that in laboratory experiments, postlarval shrimp survived and grew well over a wide range of salinities. She concluded that ". . . salinity tolerances per se may not play a direct role in the growth and survival of postlarval and juvenile shrimp in the estuarine environment."

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Brown shrimp are heterosexual. Sexes are easily distinguished by external sexual organs. See section 1.21.

Sexual dimorphism is present. At lengths exceeding 100 mm, females are longer than males of the same age (Williams, 1955).

3.12 Maturity

According to Renfro (1964), brown shrimp off Texas first spawn at a total length of about 140 mm.

3.13 Mating

Mating has never been observed, but brown shrimp are thought to be promiscuous. The male places a spermatophore inside the thelyoum of the female before eggs are spawned. Spermatophore transfer probably takes place soon after a female molts and before the exoskeleton hardens.

3.14 Fertilization

External in the open sea. We believe that fertilization occurs when the female releases eggs and sperm simultaneously.

3.15 Gonads

No detailed investigations have been made on the relation of gonad size and number of eggs to body length, weight, or age.

The following descriptions of the stages of ovarian development have been condensed from the account of Renfro and Brusher (MS) from stained histological sections:

Early developing: Abdominal lobes of ovary have a diameter equal to or slightly smaller than that of the dorsal abdominal artery. Oöcytes and small ova stain blue with hematoxylin and possess indistinct nuclei.

Developing: Diameter of abdominal lobes of ovary ranges from slightly smaller than that of the dorsal abdominal artery to almost 3 times its size. Eggs stain blue with hematoxylin and have a fine granular cytoplasm and a distinct, thick-walled nucleus.

Late developing: Ovaries are fully distended. The large irregular shaped eggs stain red with eosin.

Ripe: Ovaries are fully distended. Eggs have peripheral bodies arranged in radial patterns around nucleus. Eggs stain red with eosin, but peripheral bodies stain a lighter shade of red than the cytoplasm.

Spent: Ovaries greatly reduced in diameter; sometimes appear collapsed, and have many open spaces surrounded by follicle cells. A few unspawned eggs are usually present and rings of peripheral bodies often remain as evidence of absorption of others.

Resting: This state closely resembles early developing stage. Small eggs are loosely scattered through the ovary. Few oöcytes are being generated in zone of proliferation, and some ovaries appear to be disintegrating.

3.16 Spawning

Brown shrimp probably spawn over their entire adult range. The eggs are spawned directly into the water and there is no nesting or reproductive isolation.

Renfro and Brusher (MS), on the basis of the ovarian condition of brown shrimp in the northwestern Gulf of Mexico, came to the following conclusions: Spawning does not take place at depths of 14 m or less. At 27 m, spawning occurs from spring until early winter. The period of greatest spawning activity is in September, and a smaller peak is in May. At 46 m, spawning occurs throughout the year but peak activity is in October through December and a smaller peak extends from March to May. At 64, 82, and 110 m, spawning continues throughout the year with only slight autumn and spring increases in intensity. The greatest percentage of females in the ripe stage was found in 46 m.

After examining commercial catch statistics, Kutkuhn (1962) arrived at essentially the same conclusions as Renfro and Brusher.

Temple and Fischer (1968) took extensive plankton samples in the northwest Gulf of Mexico and concluded from the seasonal abundance of larvae that the peak of brown shrimp spawning was from September to November. Nauplii, which they believed to indicate localities and times of recent spawning, were collected at temperatures of 17.0° to 28.5° C.

Workers on the southwestern Atlantic coast of the United States, using abundance of postlarvae on the nursery grounds as evidence of spawning, reported only 1 major peak of spawning, which occurs in February or March (Williams, 1959; Bearden, 1961; Joyce, 1965). In that area, the spawning period, judged from the occurrence of postlarvae, is distinct from that of related species. Williams (1959) stated that any postlarvae entering North Carolina estuaries before mid-April are most likely to be P. azteous.

Although brown shrimp in the Gulf of Mexico spawn throughout the year, periods of heightened spawning are distinct from those of other commercially important species, the pink shrimp (P. duorarum) and the white shrimp (P. setiferus). The peak spawning periods occur earlier in the spring and later in the autumn than those of the other 2 species (Renfro and Brusher, MS; Temple and Fischer, 1968).

3.17 Spawn

The eggs are round, golden brown, and translucent. Egg diameter is 0.26 mm. When first spawned, they are adhesive but harden rapidly. Eggs are demersal, and, in the laboratory, rise in the water column only when the water is agitated (Cook, unpublished records).

3.2 Preadult phase

3.21 Embryonic phase

Development of the embryo has not been studied in detail. In the laboratory, the eggs usually hatch 14 to 18 h after spawning. The rate of embryonic development is directly correlated with temperature. The most rapid development was at 30° C, the highest temperature tested. No eggs have been hatched below 24° C.

Just before hatching, a sporadic shaking movement of the developing nauplius can be seen. At hatching, the egg case splits and the posterior portion of the nauplius protrudes. The nauplius, unmoving, appears to swell until it is forced out of the shell; this takes about 30 sec (Cook, unpublished records).

3.22 Larval phase

P. a. aztecus has 5 nauplial, 3 protozoeal, and 3 mysis substages (Cook, unpublished records). Cook (1966) reported no gross morphological differences between brown shrimp larvae he had reared and those of the pink shrimp described by Dobkin (1961).

Cook and Murphy (1966) cultured P. a. aztecus larvae from eggs spawned in the laboratory. They reported that particulate food is not required by nauplii, but that protozoae were fed diatoms and mysis stages were fed Artemia nauplii. Larvae were grown in salinities ranging from 24.1 to 36.0°/oo. Temperature affected the rate of larval development. No larvae completed metamorphosis below 24° C. Larvae reared at 24° C reached first postlarvae in 15 days, those reared at 27° C requ[illegible]d 12 days, and those reared at 30° C, only 11 days. The larvae were positively phototropic to low light intensities.

3.23 Adolescent phase

Renfro (1964) has defined the following post-mysis stages in development:

Life stage	Begins at:
Postlarva	Loss of exopods from pereiopods
Juvenile	25 mm total length; ratios of lengths of body parts assume adult proportions
Subadult	90 mm total length; female ovaries start to develop
Adult	140 mm total length; females sexually mature, capable of spawning

Williams (1953, 1959) reviewed the work of Pearson (1939) and presented criteria for separating postlarvae of brown shrimp from those of white and pink shrimp of comparable size in North Carolina. Postlarvae below 12 mm and above 18 mm total length could be separated to species. Those in the range 12 to 18 mm could not be distinguished. Baxter and Renfro (1966) reported that the characters given by Williams (1959) are useful only in separating brown and white shrimp below 10 mm total length.

Key to postlarvae under 12 mm total length (Williams, 1959).

"A. Tip of rostrum extending to distal edge of eye; third pereiopod extending to or beyond distal edge of eye.

1. Antennal scale broadly rounded distally, lateral spine exceeding tip . . . . . Penaeus aztecus

2. Antennal scale acutely rounded distally with apex near mesio-distal border, lateral spine not reaching tip (middle postlarvae with several rostral spines) . . . . . . Penaeus duorarum

B. Tip of rostrum not extending to distal edge of eye.

1. Third pereiopod extending to distal edge of eye; antennal scale acutely rounded distally with apex near mesio-distal border, lateral spine not reaching tip . . . . Penaeus duorarum

2. Third pereiopod not extending beyond distal edge of eye, often not reaching distal edge of eye . . . . Penaeus setiferus"

Recently, Ringo and Zamora (1968) detected a difference that may allow separation of postlarval brown and pink shrimp from postlarval white shrimp at all sizes. Brown and pink shrimp postlarvae have small spines on the dorsal carina of the 6th abdominal segment. The numbers and length of spines increase with increasing length of the shrimp. These spines are not present on white shrimp. By noting the presence or absence of spines, Ringo and Zamora correctly identified postlarval brown and white shrimp (5 to 25 mm total length) of known parentage. In contrast, identification of these same shrimp by using combinations of characters given by Pearson and Williams resulted in errors as great as 38 percent.

During the early postlarval stages, the shrimp are planktonic in the open sea. At a total length of about 10 to 14 mm, they migrate into the estuaries. The factor (or factors) bringing about this movement has not been identified, but several studies have been made which describe the movement of the young shrimp into the estuaries, their activity while in inside waters, and their movement back to the open sea.

It has been generally accepted that postlarvae move into the estuaries shortly after spawning has taken place, and some authors have used the appearance of large numbers of postlarvae on the nursery grounds as an indication that a period of increased spawning activity shortly preceded their arrival (see section 3.16). There is increasing evidence, however, that in the northwestern Gulf of Mexico, larvae or postlarvae, or both, overwinter in waters of the continental shelf and enter the estuaries the following spring (Temple and Fischer, 1968 Aldrich, Wood and Baxter 1968) have shown that under laboratory conditions postlarval brown shrimp burrow in response to decreasing temperatures. These authors hypothesize that ". . . burrowing is a mechanism through which P. aztecus postlarvae survive during at least a portion of the winter offshore as well as during early spring in the estuarine areas".

Baxter and Renfro (1966) collected brown shrimp postlarvae throughout the year in the surf zone along the beach at Galveston, Texas, but their numbers were greatly reduced in winter. Examination of size modes indicated that the postlarvae spend little time in the surf zone and consequently do not use it as a nursery area.

Postlarvae move into the estuaries on flood tides (Simmons and Hoese, 1959; St. Amant, Broom and Ford, 1966; Copeland and Truitt, 1966; Baxter, 1966). Simmons and Hoese (1959) and St. Amant et al. (1966) found no differences between day and night catches of postlarvae entering Mesquite Bay, Texas, and Barataria Bay, Louisiana. Baxter and Furr (1964), however, after sampling at the entrance to Galveston Bay, Texas, for 96-h period, reported that nearly 70 percent the postlarvae caught were taken at night. Copeland and Truitt (1966) determined that postlarvae entering the Aransas Pass inlet usually were nearer the surface at night; during the day, they could detect no differences between the number of shrimp taken in surface and bottom samples.

After entering estuarine waters, postlarvae concentrate in the marginal areas, usually in less than 0.9 m of water, where there is attached vegetation or abundant organic detritus, or both. The young shrimp remain in these shallow, protected areas for 2 to 4 wk; then they move into the deeper waters of the estuary before returning to offshore waters (St. Amant et al., 1966; Parker, 1966).

Aldrich (1966) observed that postlarval brown shrimp in the laboratory are capable of swimming at rates which project to 4.6 km per day. He cited field observations of R. D. Ringo which show that brown shrimp postlarvae disperse through Galveston Bay, Texas, at an average rate of 3.6 km per day.

The role salinity plays in the shrimp's life has been subject to much ivestigation. From observations in the field, various authors have reported that young shrimp are most abundant in waters of a specific salinity range. Statements as to these ranges, however, vary among authors (for examples see Parker, 1966; and St. Amant, et al., 1966). Zein-Eldin and Aldrich (1965) determined by laboratory experiments that salinity had no appreciable effect on either survival or growth except at temperature extremes. They suggested that other factors, such as food or cover, are more important than salinity in determining distribution, growth and survival of young brown shrimp.

Brown shrimp are affected greatly by temperature changes. For a detailed discussion see section 3.53.

The size at which juvenile shrimp leave the estuaries is variable. The approximate average size of brown shrimp leaving the nursery grounds in Florida is 100 to 105 mm (Joyce, 1965). Copeland (1965) reported that brown shrimp emigrate through the Aransas Pass, Texas, inlet at a total length of 70 to 80 mm. He found peak abundance of emigrants during the time of full moon in May, June, July, and August and concluded that "Apparently the high tides and faster currents that accompanied the time of full moon was enough to trigger the movement of these shrimp . . ."

Trent (1967) stated that peak abundance of brown shrimp emigrating from Galveston Bay, Texas, occurred in May and June in 1966 and that the size of shrimp leaving the bay increased as the season progressed.

Simmons and Hoese (1959) reported that all movement from Mesquite Bay, Texas, was nocturnal. They could see shrimp in the water at night; by morning none were in the water, but many were found buried in the bottom. They said "The migration in each instance began the following night, by actual observation."

Trent (1967) observed a diurnal variation in the depth distribution of the shrimp in the channel connecting Galveston Bay and the Gulf of Mexico; shrimp were near the surface at night and near the bottom during the day.

St. Amant et al. (1966) hypothesized that crowding in the estuary may cause an earlier offshore movement of smaller shrimp in some years.

3.3 Adult phase

3.31 Longevity

No technique has been developed to determine reliably the age of brown shrimp. Kutkuhn (1962) said that the average life span of the more important penaeids is about 18 mo, but that many females probably live longer.

3.32 Hardiness

See section 3.32 in synopsis on white shrimp P. setiferus by Lindner and Cook (1970) for discussion applicable to penaeid shrimp.

3.33 Competitors

See section 3.33 in synopsis on white shrimp P. setiferus by Lindner and Cook (1970) for discussion applicable to penaeid shrimp.

3.34 Predators

See section 3.34 in synopsis on white shrimp, P. setiferus, by Lindner and Cook (1970) for discussion applicable to penaeid shrimp.

3.35 Parasites, diseases, injuries and abnormalities

The following parasites have been recorded from P. a. aztecus: Class Telosporidea: Nematopsis penaeus Sprague, 1954. Trophozoites, sporonts, and gametocysts have been recorded from the intestinal tract of the host by Kruse (1959), who reported 100-percent infection in Alligator Harbor and Apalachicola Bay, Florida. Shrimp lose the infections if they are not continually reinfected (Kruse, 1959). The intestinal epithelium can be appreciably damaged (Sprague, 1954).

Cephalolobus penaeus Kruse, 1959. Trophozoites may occur in the stomach strainers (Hutton, et al., 1959; Kruse, 1959). Kruse (1959) reported 18 percent infection and an average of 8 trophozoites per shrimp in Apalachicola Bay, Florida.

Class Cnidosporidea: Thelohania sp. (Kruse, 1959). Sporonts, pansporoblasts, and spores were found "Mainly in muscles but also in other organs" in 16 percent of the shrimp examined from Alligator Harbor and Apalachicola, Florida, by Kruse (1959). Infected musculature is "white, with intermingled blue-black areas and lacks the firmness of normal muscle" (Kruse, 1959).

Nosema nelsoni Sprague, 1950. Spores may occur in muscle tissues of the entire body (Sprague, 1950). The flesh of infected shrimp is soft and milky white. Some bait dealers believe that infected shrimp do not keep well and die in a short time (Hutton et al., 1959).

Class Cestoda: Prochristianella penaei Kruse (1959). Plerocerci occur in "Digestive gland and tissues surrounding digestive gland and stomach, blastocysts of larvae frequently penetrating wall of digestive gland" (Kruse, 1959). Adults have been recorded from the ray, Dasyatis sabina, by Aldrich (1965). In the northeastern Gulf of Mexico, Kruse (1959) reported 90.6 percent of the shrimp infected, with an average of 6.2 plerocerci per shrimp. Aldrich (1965) reported 45 percent infection in the Galveston, Texas, area. Both the incidence and intensity of infection increase with the size of the shrimp up to about 14 mm carapace length (Aldrich, 1965). Aldrich (1966), working in the laboratory with infected brown shrimp, concluded that shrimp mortality over a 5-wk period was not caused by P. penaei. In addition, he stated that the time spent in the shrimp by the parasite exceeds 5 wk.

Cestode larvae have been recorded from the internal lining of the midintestine by Kruse (1959), who reported 16.4-percent infection in Alligator Harbor and Apalachicola, Florida. Numbers per shrimp ranged from 27 to 122.

Class Nematoda: Contracaecum sp. (Hutton et al., 1959). Juveniles have been found "In digestive gland and tissues surrounding digestive gland and stomach, not encysted" (Kruse, 1959). In Alligator Harbor and Apalachicola Bay, Florida, 2.3 percent of the shrimp were infected (Kruse, 1959). Hutton et al., (1959) reported a 2.8-percent infection in shrimp collected from widely scattered areas. The greatest number in a single specimen was 2.

3.4 Nutrition and growth

3.41 Feeding

See section 3.41 in synopsis on white shrimp P. setiferus by Lindner and Cook (1970) for discussion applicable to penaeid shrimp.

3.42 Food

In North Carolina, the stomachs of adult and young shrimp from the estuaries were full or half filled in the autumn, nearly always empty in the winter, and usually full in the summer (Williams, 1955). In addition, Williams (1955) reported that stomach contents were macerated and hard to identify. The most abundant material was ". . . usually a mass of unrecognizable debris, probably a mixture of digesting tissue and organic deposit from the bottom . . . Most of the materials, except the muscle fibers and unrecognizable debris, are hard. Although they indicate types of food that shrimp eat, they are too hard to be triturated easily and, because large fragments will not pass through the straining apparatus in the pyloric stomach, hard parts may accumulate in quantity in the stomach. Whether most of these hard materials are further broken down for alimentation or are regurgitated is not known, but unrecognized softer and more easily digested materials could easily form the bulk of the diet" (Williams, 1955).

3.43 Growth rate

Growth of P. a. aztecus is related directly to temperature. Zein-Eldin and Griffith (1966) reported the results of laboratory experiments in which postlarval brown shrimp were held at temperatures ranging from 15° to 35° C. They stated, "Growth increased with temperature up to 32.5° C. Maximal increases of growth rate per unit of temperature were observed in the temperature range of 17.5° to 25° C," and, when mortality is considered, ". . .in the laboratory gross production is optimal at temperatures of 22.5° to 30° C." In an earlier experiment (Zein-Eldin and Aldrich, 1965), postlarvae held in the laboratory for 1 mo at 11° C exhibited almost no growth.

Growth estimates of postlarval and juvenile P. a. aztecus on the nursery grounds range from 1.0 to 2.5 mm per day (Williams, 1955; Loesch, 1965; Joyce, 1965; St.Amant et al., 1966; Shrimp Biological Research Committee, 1966). Loesch stated "Brown shrimp spawned in late summer grew 13 to 18 mm per month from November to April, and 30 to 35 mm per month from April to May. The apparent early summer growth rate of March-spawned brown shrimp was 30 to 43 mm per month. Very young brown shrimp may grown as much as 50 mm per month." St.Amant et al. (1966) studied the growth of P. a. aztecus in Barataria Bay, Louisiana, during March, April, and May from 1962 to 1965. Rate of growth varied from nil to 2.5 mm per day. They observed "There appeared to be a trend, though not completely evident in these data, for the growth of brown shrimp to be less than 1.0 mm per day when the water temperature was below 20°C and less than 1.5 mm per day when the water temperature was below 25°C. Little or no measurable growth was noted at cumulative average water temperatures below 16°C."

There are no published data on growth during the offshore or adult phase of the life cycle.

Wheeler (1967) computed the coefficient of condition (K) of shrimp grown in ponds. The factor K was derived by the formula:

$$K = \frac{10^6 \ W}{L^3}$$

where W = weight in grams and L = length in millimeters. The highest value he recorded was 8.22. During rapid growth, the K value was above 7.2.

A maximum conversion rate of 53 percent was calculated by Zein-Eldin and Aldrich (1965) for postlarvae fed Artemia nauplii. They also learned that efficiency of food conversion varied with temperature and salinity. Griffith (1966, and personal communication) isolated 4 postlarvae of 12 to 18 mm and fed them brine shrimp nauplii. He then calculated individual feeding rates as the shrimp grew through the 18-to 38-mm size interval. The feeding efficiencies and the time required for each shrimp to grow 20 mm were: 45 percent, 12 days; 43 percent, 20 days, 43 percent, 21 days; and 34 percent, 20 days.

3.44 Metabolism

Williams (1960) and McFarland and Lee (1963) have demonstrated that P. a. aztecus adults and juveniles regulate hyperosmotically in low-salinity water (under 30‰) and hyposmotically in high-salinity water. Most shrimp tested by McFarland and Lee withstood dilutions down to 5 to 6‰. Further dilution caused complete loss of equilibrium and almost complete mortality after 24 h. Williams (1960) found that at temperatures of 8.7° to 8.8° C the shrimp's ability to regulate is impaired and its blood tends toward isotonicity.

Brown shrimp also regulate the ionic concentration of Na, Cl, K, Ca, and Mg, in their serum (McFarland and Lee, 1963).

Love and Thompson (1966) isolated 23 amino acids from brown shrimp tails and offal. Concentrations of a number of amino acids varied seasonally. Concentrations of a number of amino acids also differed between P. a. aztecus and P. setiferus. For a more detailed discussion of this work see section 3.44 of synopsis on Penaeus setiferus by Lindner and Cook (1970).

3.5 Behaviour

3.51 Migrations and local movements

See section 3.23 for movements of postlarvae and juveniles.

Little is known about the movements of adult P.a.aztecus. Commercial catch statistics show that the shrimp gradually move offshore into deeper water after leaving the estuaries. Berry (1964) suggested, however, "... that seasonal migration is not an important cause of differences in the frequency with which size groups enter catches made at depths greater than 25 fathoms."

McCoy and Brown (1967) performed a mark-recapture experiment in North Carolina from June through October 1966. The results, based on a limited number of returns, indicated that after leaving Beaufort Inlet, the shrimp migrated southward down the coast. The greatest distance traveled was about 241 km in 5 wk.

Klima (1963), reporting the results of several mark-recapture experiments with brown shrimp in the northwestern Gulf of Mexico, stated that during the period April through June, most shrimp did not move great distances—usually less than 48 km. Movement was parallel to the coast, between the 29-and 55-m (16-and 30-fm) contours. The greatest distance travelled was about 314 km.

After examining commercial landings, Gunter (1962) believed that the brown shrimp population moves southward along the Texas coast during autumn and winter.

3.52 Schooling

Brown shrimp do not school extensively (Hildebrand, 1954).

3.53 Responses to stimuli

Williams (1958) who tested the preference of juvenile P.a.aztecus for different substrates, learned that they occur most frequently on the muddier substrates. He also noted that the small shrimp do not burrow very often on a shell-sand substrate, but tend to hide in interstices at the surface. The adults occur mostly on mud or silt bottoms (Springer and Bullis, 1954; Hildebrand, 1954).

Young shrimp are tolerant of wide fluctuations in salinity. They have been taken in salinities as low as 0.22‰ (Gunter and Hall, 1963) and as high as 69‰ (Simmons, 1957). Zein-Eldin and Aldrich (1965) found that, in the laboratory, salinity had little or no effect on either survival or growth of postlarvae except at extreme temperatures. Tolerance was reduced at salinities below 10‰ at 7° and 15° C. McFarland and Lee (1963), in their study of the ability of brown shrimp to regulate body fluids (see section 3.23), concluded that this species is physiologically adapted to tolerate high salinities. They suggested that tolerance of high salinities is gained by sacrifice of a degree of regulatory capability at low salinities.

Juvenile brown shrimp (83 to 110 mm total length) have an average oxygen consumption of 0.31 ml O_2/g/h after a 10-min exercise period (Zein-Eldin and Klima, 1965). These authors also learned that a 0.5-percent fast green (FCF) stain injection did not affect oxygen uptake of the shrimp.

Temperature has a pronounced effect on growth and survival of postlarvae in the laboratory. At 11° C, growth is essentially nil (Zein-Eldin and Aldrich, 1965). Zein-Eldin and Griffith (1966) reported that rate of growth increases with temperature up to 32.5° C. Survival for 1 mo was greatly reduced at 32.5° C, and no shrimp survived at 35° C. They calculated that gross production is best at temperatures between 22.5° and 30°C. From field observations, St. Amant, Corkum, and Broom (1963) reported that no appreciable growth can be seen in brown shrimp postlarvae at temperatures below 20° C. Laboratory experiments by Zein-Eldin and Griffith (1965) suggested that temperature influences growth through a change in molting rate rather than by affecting the increase in size per molt.

Under controlled conditions in the laboratory, Aldrich et al. (1968) observed that postlarval P. a. aztecus burrowed as temperatures were reduced to 12° to 17° C and emerged as the temperature was increased to 18° to 21.5° C. The authors discussed this behaviour in relation to the seasonal pattern of abundance and suggested that it may have survival value during cold weather.

The offshore fishery for brown shrimp is a nighttime fishery. These shrimp usually burrow during the day and are active at night. Joyce (1965) reported that in inshore waters of northeast Florida, 71 percent of the shrimp he sampled were caught during the day, whereas at offshore stations (average depth, 12.1 m) he caught 51 percent at night. Springer and Bullis (1952) said that differences in day and night catch rates were not as apparent in the deeper waters as in the shallow waters of P. a. aztecus range.

Fish meal and dog food are used to attract shrimp in Florida (Joyce, 1965).

4 POPULATION

4.1 Structure

4.11 Sex ratio

1:1 (Renfro and Brusher, 1963; Joyce, 1965).

4.12 Age composition

Age composition of the catch varies directly with recruitment and movement of the maturing shrimp to offshore waters (Kutkuhn, 1962).

4.13 Size composition

In the lesser depths of their range, seasonal size composition varies with recruitment in the same manner as age composition. Berry (1964) presented evidence that the influence of seasonal emigration from the estuaries does not have a great effect on seasonal size composition at depths greater than 46 m (25 fm).

Size distribution of brown shrimp is related to both distance from shore and water depth. Larger shrimp are generally taken from deeper water. However, shrimp taken from a given depth near shore were smaller than shrimp taken at the same depth farther offshore (Renfro and Brusher, 1964).

Kutkuhn (1962) showed modal-size distributions of the commercial catch off the U.S. and east Mexican Gulf coast for 1956 to 1959. Weights of older shrimp are greater in proportion to their length than are those of younger ones. The length-weight relationship of juvenile and sub-adult shrimp in Texas is expressed by the following equation:

$$\text{Log } W = -5.483 + (3.190)(\text{Log } L)$$

There is no appreciable difference in length-weight relationships between sexes (Chin, 1960).

4.2 Abundance and density of population

4.22 Changes in abundance

See section 5.43 for annual catch statistics for the U.S. Gulf coast. These data show that abundance, as reflected by catch, varies greatly from year to year. Berry (1966), has presented evidence that the fluctuations are caused by annual variations in the survival of shrimp larvae. He stated, "In years of high abundance, brown shrimp are plentiful over the entire area (Mobile Bay to U.S. - Mexican border), and during years of low abundance, brown shrimp are scarce over the area. The factors responsible for such wide-spread fluctuations in abundance are unknown, but are assumed to be linked to oceanographic conditions".

4.23 Average density

Kutkuhn (1962) ascertained that in the Gulf of Mexico, the brown shrimp have a gradient of abundance. He stated, "Indices similarly derived for all species and areas, and averaged over all months for the years 1956 through 1959, revealed a steady increase from east to west in the mean harvestable biomass of this species ... Maximum stock density now occurs off Texas and eastern Mexico ..."

4.24 Changes in density

Kutkuhn (1962) derived a fishable biomass index which reflected changes in density off the U.S. and east Mexican Gulf coast between 1956 and 1959.

4.3 Natality and recruitment

4.33 Recruitment

Rate of recruitment has not been determined. Because there is evidence of year-round spawning, there is also probably year-round recruitment in some areas. Major recruitment of postlarvae into the estuaries starts in late January or February, reaches a peak in March or April, and continues until June (Williams,1955, 1959; Bearden, 1961; Baxter and Renfro, 1966). Subsequent entry into the offshore fishery starts in May and continues until August (Shrimp Biological Research Committee, 1966).

4.4 Mortality and morbidity

4.41 Mortality rates

Berry (1964) estimated total mortality at 66 percent per mo in offshore waters. Klima (1963) postulated a fishing mortality rate of 21 percent a mo and a 60 percent natural mortality rate.

4.42 Factors causing or affecting mortality

Similar annual fluctuations in abundance of brown shrimp over broad and widely separated areas of the Gulf were interpreted by Berry (1966) and Berry and Baxter (1969) as meaning that factors such as differences in fishing intensities and in laws governing harvesting practices have but little effect on population levels. Berry (1966) stated that these annual fluctuations were caused by oceanographic conditions during the larval phase of development. He concluded that "... present harvesting practices probably have little real effect on the abundance or long-term welfare of shrimp stocks".

Several authors have postulated that adverse conditions in the estuaries during the time that the young shrimp are most abundant cause reduction in subsequent offshore catches. In South Carolina, Bearden (1961) suggested that a cold wave in 1960 might have killed the postlarvae, resulting in a low commercial catch for that year. St.Amant et al. (1966) believed that depressed salinity values, resulting from unusually heavy rains, caused the 1965 Louisiana production to be low.

4.5 Dynamics of population (as a whole)

Baxter (1963) pointed out that the abundance of postlarvae as they enter the estuaries may provide an index from which annual harvests can be predicted. Usually, the numbers of postlarvae are positively correlated with subsequent juvenile abundance in the estuaries as well as with the commercial harvest offshore (Louisiana Wild Life and Fisheries Commission, 1964; Lunz, 1965; Anonymous, 1965; Christmas, Gunter and Musgrave, 1966; Berry and Baxter, 1969). St. Amant et al. (1966) questioned the reliability of this method; they believed that the density of juveniles shows a better correlation with future production.

Berry and Baxter (1969) agreed that indices based on juvenile abundance show a better correlation with offshore production, but they made the following distinction: "In spite of the variation associated with collections of postlarvae, we believe the predictions based on postlarval indices have greater potential value than those made from juvenile shrimp catches because information is available 4 to 6 weeks sooner."

4.6. The population in the community and the ecosystem

Hildebrand (1954) made an extensive survey of macrofauna on Gulf of Mexico brown shrimp grounds. The dominant organisms were Penaeus aztecus, Callineotes danae, Pitar cordata, Busycon contrarium, Astropecten antillensis, Syacium gunterii, and Poronotus tricanthus.

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gears

The most common gear used is the otter trawl. Most offshore trawlers fish two 12-to 14-m flat or balloon trawls, and smaller vessels in the inshore fishery commonly fish only one net, usually 15 m. The trend is toward larger nets; however, 28 new boats which entered the fishery at Aransas Pass, Texas, in 1966, towed paired 15- to 21-m nets (James Lyon, personal communication).

The size and construction of the otter trawls used vary greatly, depending on area fished, vessel size, and species of shrimp. Robas (1959) and Fuss (1963, 1963a) gave construction diagrams of the types of trawls used most commonly in the Gulf of Mexico. Robas' diagram of the 12-m flat trawl calls for 15-thread, 5.7-cm stretched mesh cotton webbing in the body of the net, and 42-thread, 5-cm stretched mesh cotton in the cod end. In recent years, however, more fishermen have been using synthetic twine, especially in larger nets (Juhl, 1961). The wings of the net are attached to wooden otter boards (trawl doors) which spread the net as it is towed. The size of the doors varies with the size of the net; those used with a 13-m net are about 213 cm long by 81 cm high (Robas, 1959). The average length-height ratio for all doors is 2.4:1. Each door is attached by chains to 6-to 8-m bridles which extend from the main towing cable (Juhl, 1961). By adjusting the chains, the downward and outward thrust of the doors can be regulated to make the net fish properly (Robas, 1959). Also attached between the doors is a jumper or "tickler" chain which rides in front of the footrope when the trawl is fished (Guest, 1958); it is adjusted to ride from 0.3 to 1.8 m in front of the footrope (Fuss, 1963a).

In the past, lead seine weights were generally used to weight the footrope. Today, varying lengths of 6.35-mm galvanized chain are more common. Hollow plastic or plastic foam floats are becoming more popular than cork or rubber floats for headrope flotation (Fuss, 1963a).

A try net, which is a miniature trawl, is often used to locate fishable concentrations of shrimp and to monitor their abundance during the 1½-to 5-h drags (Guest, 1958; Kutkuhn, 1962). Lindner (1957) reported that most Mexican fishermen set out lighted marker buoys for positioning concentrations of shrimp during night fishing. Thes buoys are also used by U.S. fishermen.

In addition to trawls, a great variety of gear is used in the coastal and bay fisheries. These include frame trawls, haul seines, channel nets, lift nets, pushnets, cast nets, dip nets, and trap nets or weirs (Inglis and Chin, 1966; Lindner, 1957; Broad, 1951).

Lindner (1957) described a type of trap or weir called "Charangas" which is used on the east coast of Mexico in the Laguna Tamiahua. Cut brush is stuck in the mud in shallow water in the form of a "V" with the sides 9 to 30 m long and with the opening facing the outgoing tides. A fiber-meshed screen is placed in a 0.6-to 0.9-m opening at the apex of the "V". Usually several charangas are connected in series. Fishing is done at night with lanterns hung over the screens. As the shrimp congregate near the screens, fishermen scoop them out with dip nets.

5.12 Boats

In the inshore fishery, vessels of all types are used, ranging from unpowered dugouts (Lindner, 1957) to large trawlers.

The most common vessel in the offshore fishery is the double-rigged, Florida-type trawler. "The Florida-type hull usually has a round bottom, flared bow, and a broad square transom stern. The deckhouse is forward and the clear fishing deck, aft. Nets are towed from booms. The engine room is under the deckhouse and fish holds are aft. The majority of the vessels range from 55 to 70 feet in length, with a few as long as 75 to 80 feet or more. Typically, the vessels are diesel powered and use cable rigs with drum hoists powered from the main engine." (U.S. Fish and Wildlife Service, 1958). The winches are usually 3-drum (Robas, 1959).

Almost all older vessels are of wood construction. The trend in new vessels is to steel hulls. Most shipyards are now building ships from stock designs, many of which are 22 m or longer (Anonymous, 1966). About 64 percent of the shrimp trawlers constructed in the United States in 1966 were over 21 m (Anonymous, 1966a). The most common types of electronic equipment are automatic pilots, depth recorders, and radio telephones (U.S. Fish and Wildlife Service, 1959). Most vessels carry ice to refrigerate the shrimp.

A few "mother" or support ships operate occasionally. These vessels, 30 to 45 m long, are equipped with the necessary crew for heading and freezing the catch (U.S. Fish and Wildlife Service, 1958).

5.2 Fishing areas

5.21 General geographic distribution

See section 2.1.

5.22 Geographic ranges

The accompanying map (Fig. 1), which delin-

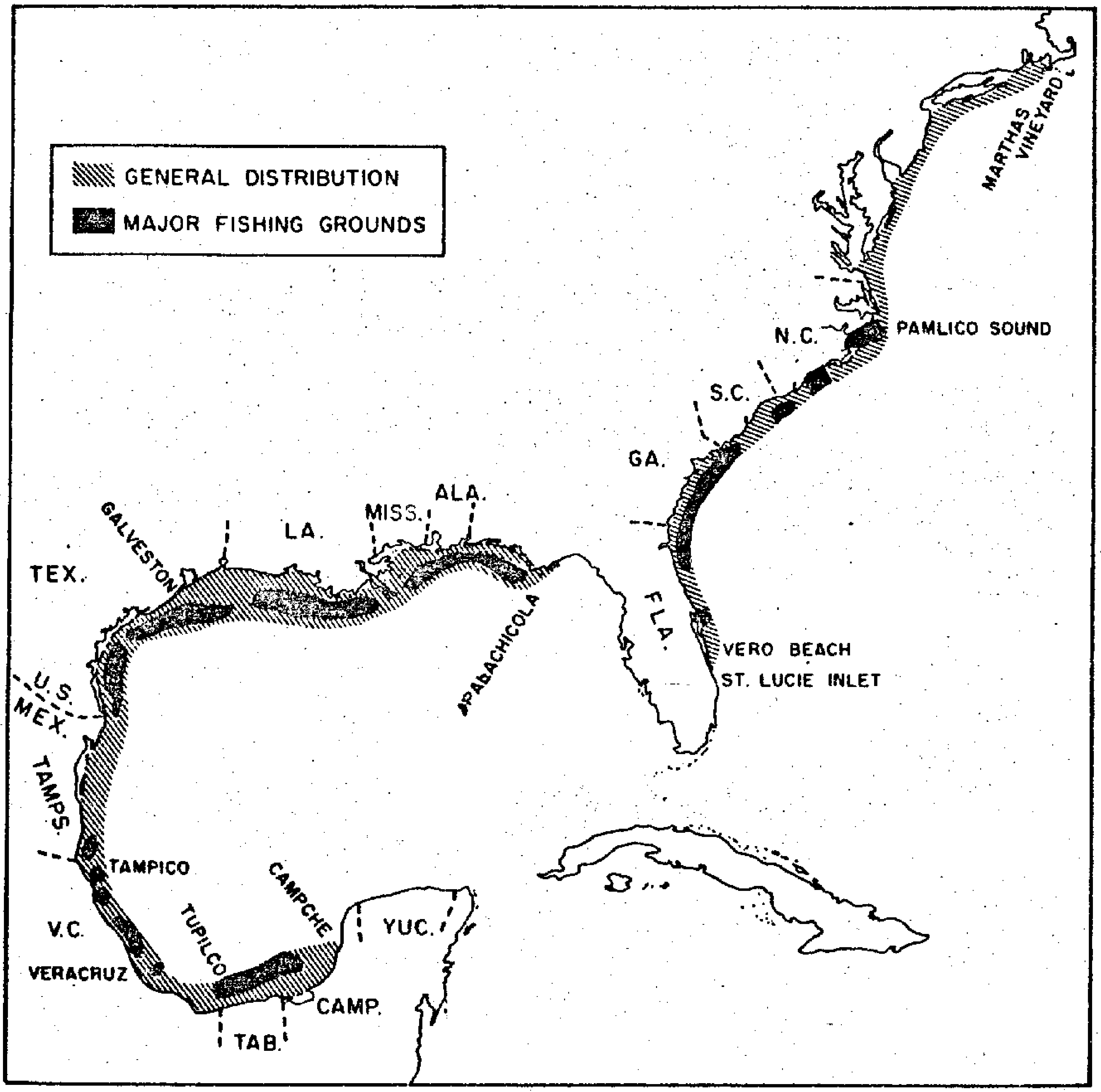

Fig. 1 Distribution and major fishing areas for Penaeus aztecus aztecus.

eates the primary fishing areas, is adapted from Hildebrand (1954), Anderson and Lunz (1965), Lindner (unpublished observations), and George Snow (personal communication).

5.23 Depth ranges

See section 2.1.

5.3 Fishing seasons

5.31 General pattern of season(s)

The brown shrimp fishery is a year-round fishery.

5.32 Dates of beginning, peak, and end of season(s)

Greatest catches are made usually over a 4-or 5-mo period after the young of the year have moved to the offshore waters. For example, in 1956-59, almost 74 percent of the brown shrimp catch in Texas was landed in July to October (Gunter, 1962). This period of peak catch varies over the range of the species. The peak catches for the period 1956 to 1959" . . . usually occurred during July-August off Louisiana, August-October off Texas, and September-November off eastern Mexico." (Kutkuhn, 1962).

5.4 Fishing operations and results

5.41 Effort and intensity

The shrimp fishery is a mixed fishery in which landings are frequently composed of several species. In areas where effort is recorded. it is reported only for the dominant species and not for the individual species. As a result, no reliable effort information for brown shrimp has been published.

Lassiter (1964) described several factors affecting fishing effort that are applicable to the brown shrimp fishery. After examining the records of 1,000 boats for a 3-yr period (1959 to 1961), he reported that ". . . average landings and days fished increased with vessel size, at least through the 60-to 69-ton class." He attributed this relation to the fact that a high percentage of larger vessels were active throughout the year, being able to fish under conditions that kept smaller boats in port. The average increase in landings for each day fished by the larger vessels was 333 kg in 1959, 348 kg in 1960, and 280 kg in 1961.

5.42 Selectivity

There have been few studies on the selective properties of gear. Hildebrand (1954) observed that fishing qualities differ considerably between nets and that fishermen frequently make adjustments to the weight or set of the otter boards or change the length of the jumper or "tickler" chain. He concluded that "Consequently there is no standard gear even during a single fishing trip."

Roelofs (1950) demonstrated that with nets having a 5-cm mesh cod end, escapement of shrimp 90 mm in total length was about 10 percent, and escapement of shrimp 135 mm or longer was almost nil. When the mesh of the cod end was 5.7 cm, the 10-percent level of escapement was not attained until the shrimp reached a length of 115 mm; again no escapement was recorded for shrimp 135 mm or longer.

More recently, Berry and Hervey (1965) obtained a straight line relation between the length of shrimp retained by a cod end and its stretched mesh size. They also demonstrated that the selective action of cod ends of different mesh size varied with the length of time the trawls were fished.

These authors also learned that the size of mesh in the body of the net affects the width of the mouth of the net when it is fished. Nets constructed of 4-and 5-cm mesh had an average distance between the doors of 9.3 and 9.4 m, respectively; those with 6-cm mesh, 11 m; and those with 7.6-cm mesh, 11.3 m. The authors specualted that the catches of large shrimp with 6-and 7.6-cm mesh nets should exceed those with 4-and 5-cm mesh nets by 15 and 20 percent.

In most areas, the market price of shrimp is based on size; the larger shrimp command higher prices. As a result, fishermen frequently fish in areas where large shrimp are abundant and pass by areas with too many small shrimp. Also, varying quantities of small shrimp are frequently discarded by U.S. boats, either because they do not meet minimum size requirements or because the fishermen do not want to bother with them.

Most shrimp fishermen fish for more than one species of shrimp, diverting their effort from one species to another as abundance changes. It is not uncommon for boats to travel considerable distances in search of better catches. For instance, boats based on the Atlantic coast of Florida frequently fish along the Louisiana and Texas coasts.

5.43 Catches

The first large catches of brown shrimp in the United States were in 1947 (Springer, 1951); however, accurate records of the catch before 1957 are not available.

Table I gives the U.S. landings for 1957 through 1965. These figures do not include catches made in the bait fishery or non-commercial production, which in some areas are substantial.

TABLE I

U.S. brown shrimp landings in metric tons whole weight

Year	Atlantic coast	Gulf coast	Total
1957	4,391	46,469	50,860
1958	4,169	37,429	41,598
1959	4,280	50,965	55,245
1960	4,100	48,123	52,223
1961	1,132	28,592	29,724
1962	5,231	30,246	35,477
1963	3,468	40,882	44,350
1964	3,216	30,789	34,005
1965	3,686	45,578	49,264

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

Regulations vary throughout the brown shrimp fishery. The following types of regulatory measures are commonly enforced.

6.11 Limitation or reduction of total catch

(i) Requirements for licenses or permits.

(ii) Limitations on catch in inside waters.

6.12 Protection of portions of population

(i) Limitations on size and type of gear used.

(ii) Limitations on size of shrimp permitted to be taken and landed.

(iii) Permanent and temporary closure of inside waters.

(iv) Closure of inside waters to night fishing

(v) Temporary closure of outside waters to territorial limits.

6.2 Control or alteration of physical features of the environment

See section 6.2 of Synopsis on P. setiferus (Lindner and Cook, 1970).

6.3 Control or alteration of chemical features of the environment

Shrimp are vulnerable to agricultural pesticides (Chin and Allen, 1957; Butler, 1962, 1963, 1966; Butler and Springer, 1963). For a detailed discussion see section 3.32 of Synopsis on P. setiferus by Lindner and Cook (1970).

6.4 Control or alteration of the biological features of the environment

No attempts have been made to control the biological environment of the species.

6.5 Artificial stocking

The species has not been used for artificial stocking.

7 POND FISH CULTURE

7.1 Procurement of stocks

There are no commercial pond-culture operations for P. a. aztecus; all attempts to culture them have been experimental.

For experimentation, most workers have had to rely on naturally produced postlarvae and juveniles to stock ponds. The most common practice is to catch postlarvae as they migrate into the bays in large numbers. Recently, a method has been developed that has proved reliable for culturing small numbers of larvae (Cook and Murphy, 1966; Cook, 1969). With this method, enough postlarvae have been reared to stock small experimental ponds, but further refinement is necessary before sufficient numbers can be supplied for large-scale pond culture.

7.3 Spawning (artificial; induced; natural)

Brown shrimp, when held in the laboratory, have not developed mature ovaries and spawned. If in spawning condition when captured, however, they will spawn readily in the laboratory, usually on the night following their capture. A high percentage of the eggs hatch, but survival of the larvae in mass culture has been low (Cook and Murphy, 1966; Cook, 1969).

7.5 Pond management (fertilization; aquatic plant control; etc.)

Rotenone in a concentration of $1.5/10^9$ has been used to control predaceous fish without killing shrimp or other crustaceans. Lorio (1967) removed predators by treating ponds with rotenone at 2 ppm before stocking.

A soluble inorganic fertilizer (3:2:1) was added by Wheeler (1967) to a 1/20-ha pond to encourage the growth of phytoplankton and indirectly increase the animal life. During the first 55 days, the shrimp in this pond grew an average of 1.2 mm a day; however, they did not increase appreciably in length and actually lost weight during the remaining 49 days of the experiment.

7.6 Foods; feeding

Wheeler (1967) tried to accelerate shrimp growth in a 1/20-ha unfertilized pond by daily adding supplemental food consisting of ground fish and shellfish (64 percent by weight) mixed with a commercially produced livestock food (36 percent by weight). During the 3-mo experiment, daily increases averaged 0.9 mm in length and 0.073 g in weight. In a 95-day growing period, production from this pond was 13.3 kg.

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